Lightning Observations from the International Space Station (ISS) for Science Research and Operational Applications

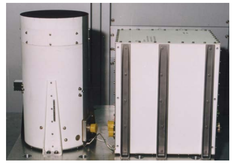
R. J. Blakeslee[1], H. J. Christian[2], D. M. Mach[3], D. E. Buechler[2], W. J. Koshak[1], T. D. Walker[2], M. Bateman[3], M. F. Stewart[2], S. O'Brien[2], T. Wilson[2], S. Pavelitz[1], C. Coker[1]

[1]NASA Marshall Space Flight Center (email: rich.blakeslee@nasa.gov, phone: 256-961-7962), [2]University of Alabama in Huntsville, [3]Universities Space Research Association (USRA)

Introduction and Overview

Mission

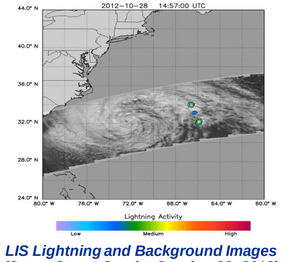
- Fly a space-qualified, flight-spare LIS on ISS to take advantage of unique capabilities provided by the ISS *(e.g., high inclination, real time data)*.
- Integrate LIS as hosted payload on DoD Space Test Program Houston 5 (STP-H5) mission and launch on Space X rocket in January 2016 for a minimum 2 year mission.



Flight Spare LIS

Measurement

- NASA, the University of Alabama in Huntsville (UAH) and their partners developed and demonstrated effectiveness and value of space-based lightning observations as a remote sensing tool.
- LIS measures total lightning (*amount, rate, radiant energy*) during both day and night, with storm scale resolution, millisecond timing, and high, uniform detection efficiency.
  - **LIS daytime detection is especially unique and scientifically important (>70% occurs during day).**
  - **Also, LIS globally detects TOTAL (*both cloud and ground*) lightning with no land-ocean bias.**



LIS Lightning and Background Images (Super Storm Sandy October 28, 2012)

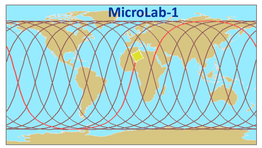
Need and Benefit

- Lightning is quantitatively coupled to both thunderstorm and related geophysical processes, and therefore provides important science inputs across a wide range of disciplines (*e.g., weather, climate, atmospheric chemistry, lightning physics*).
- ISS LIS (*or i LIS as Hugh Christian prefers*) will extend TRMM time series observations, expand latitudinal coverage, provide real time data to operational users, and enable cross-sensor calibration.

LIS Flight Heritage

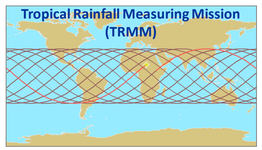
Optical Transient Detector

Launched: April 1995
Data: May 1995 - April 2000
Orbit: 70° inclin., 735 km
(detects to ~75°)
Field of view: 1250 x 1250 km
Diurnal cycle: sampled in 55 days



Lightning Imaging Sensor

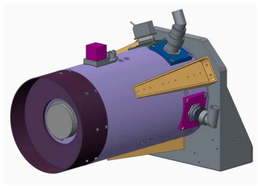
Launched: November 1997
Data: January 1998 - April 2015
Orbit: 35° inclin., 350 km
(boosted to 400 km in 2001)
Field of view: 600 x 600 km
Diurnal cycle: sampled in 49 days

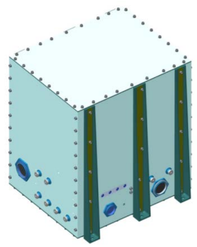


- ISS LIS builds upon a solid foundation of previous on-orbit observations, extending 20 years.
- Key LIS scientists, engineers, and facilities are still in place to support this mission.
- Well established processing, archival, and distribution systems assures ISS LIS data will be quickly placed into the hands of the science user community.

LIS Hardware (Heritage and New)

(heritage) *(new)*





Sensor Unit

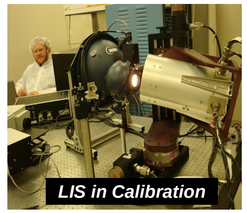
- Optical Assembly
- 128x128 CCD Focal Plane
- Lightning and Background detection

Electronics Unit

- Real Time Event Processor and Background removal
- Control & Data Handling (C&DH)
- Power conversion and control

Interface Unit

- Power conversion
- 1 PPS Time Signal
- C&DH Formatting
- ISS Interface

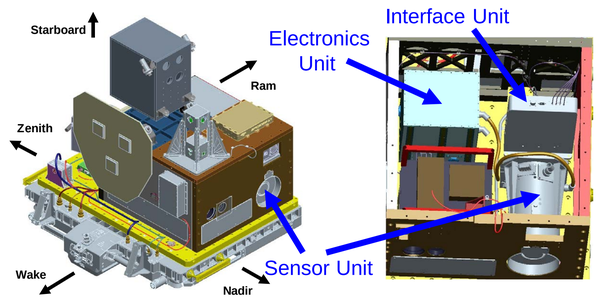


LIS in Calibration

Field-of-View (FOV)	80° × 80°	Measurement Accuracy	
Pixel IFOV (nadir)	4 km	location	1 pixel
Interference Filter		intensity	10 %
wavelength	777.4 nm	time	tag at frame rate
bandwidth	1 nm	Dimensions	
Detection Threshold	4.7 μJ m^{-2} sr^{-1}	sensor assembly	20 × 37 cm
Signal to Noise Ratio	6	electronics assembly	31 × 22 × 27 cm
CCD Array Size	128 × 128 pixels	Weight	20 kg
Dynamic Range	> 100	Power	30 Watts
Detection Efficiency	~ 70 - 90 %	Telemetry	
False Event Rate	< 5 %	data rate, format	8 kb/s, PCM

LIS Performance Parameters

LIS Integration as Hosted Payload on STP-H5

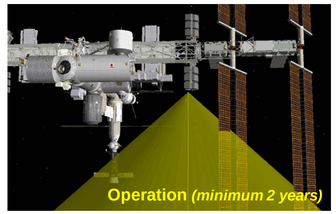


- LIS is one of thirteen instruments on the STP-H5 payload manifest.
- LIS will be installed on ISS in an Earth viewing (nadir) position.
- Payload built to allow robotic installation on ISS.

LIS Launch, Installation and Operation on ISS

- Launch on a Space X rocket with Dragon cargo vehicle in January 2016.
- Robotically installed on an external truss (ELC-1) in position shown.
- Operated for 2 years, but will seek mission extension from NASA.

Launch (January 2016)



Operation (minimum 2 years)

Science and Applications from LIS Lightning

Weather: Total lightning is strongly coupled in a quantitative way to thunderstorm processes and responds to updraft velocity and cloud particles (concentration, phase, type, and flux).

- **LIS acts like a radar in space: it reveals the heart of the cloud.**
- **Lightning can improve convective precipitation estimates.**
- **Lightning is strongly coupled to severe weather hazards (*winds, floods, tornadoes, hail, wild fires*) and can improve forecast models.**

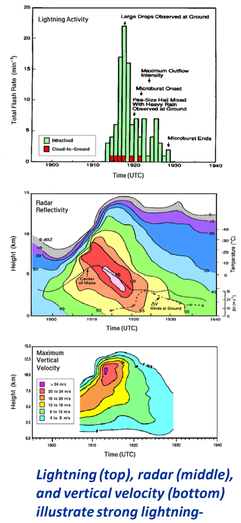
Climate: Lightning is an excellent variable for climate monitoring because it is sensitive to small changes in temperature and atmospheric forcing. ISS LIS will:

- **Extend 16 year time series of TRMM LIS, expand to higher latitudes.**
- **Monitor the occurrence and changes in extreme storms.**
- **Provide much desired cross-sensor calibrations between platforms.**

Chemistry: ISS LIS will help improve estimates of lightning produced NO_x for climate and air quality studies.

- **Lightning NO_x also impacts ozone, an important green house gas.**
- **Climate most sensitive to ozone in upper troposphere, exactly where lightning is the most important source of NO_x.**

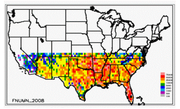
Other: Complementary ISS LIS observations will help unravel the mechanisms leading to terrestrial gamma-ray flashes (TGFs) and Transient Luminous Events (TLEs).



Lightning (top), radar (middle), and vertical velocity (bottom) illustrate strong lightning-storm coupling

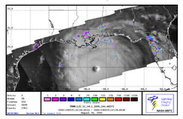
Unique Science Contributions from ISS Platform

- ❑ Lightning coverage at higher latitude missed by TRMM
  - **TRMM LIS missed up to 30% lightning in N. Hemisphere summer**
  - **Enhance regional and global weather, climate, and chemistry studies**
  - **Provide CONUS coverage (*needed for National Climate Assessment*).**



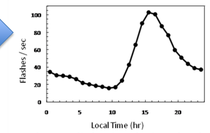
TRMM LIS did not cover CONUS for climate and chemistry assessments

- ❑ Real time lightning using ISS for operational applications
  - **Provide real time lightning in data sparse regions, especially oceans (*storm warnings, nowcasts, oceanic aviation and international SIGMETs, long-range lightning system validation, hurricane rapid intensification evaluations*).**
  - **Desired by NASA and strongly endorsed by NOAA partners (*partners include: NWS Pacific Region, Joint Typhoon Warning Center, Ocean Prediction Center, Aviation Weather Center, and National Hurricane Center*).**



Real time lightning useful for operations (LIS in Hurricane Katrina)

- ❑ Enable simultaneous / complementary observations with other ISS payloads
  - **Provide critical daytime lightning to better understand mechanisms leading to TGFs and TLEs (*strongly endorsed by ESA ASIM and JAXA GLIMS*).**
- ❑ Support cross-sensor calibration and validation activities
  - **Inter-calibrate ISS LIS, TRMM LIS, GOES-R GLM and MTG LI for improved science and applications (*strongly endorsed by NOAA and ESA*).**



LIS detects lightning during the day when most lightning occurs

Summary

- There exist several core science applications of LIS lightning observations, that range from weather and climate to atmospheric chemistry and lightning physics due to strong quantitative connections that can be made between lightning and other geophysical processes of interest.
- The space-base vantage point, such as provided by ISS LIS, still remains an ideal location to obtain total lightning observations on a global basis.